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A Comparative Analysis of Queuing and Fuzzy Logic based Admission Control Schemes in CDMA Cellular Network

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Abstract

In CDMA cellular system, the coverage area of the cell is greatly influenced by soft handoff process. The variation in soft handoff coverage area can be taken as the parameter influencing the performance parameters of the CDMA cellular system. This paper is concerned with a comparative analysis of two queuing based call admission control schemes with a fuzzy based CAC (call admission controller) model. The analytical models developed are based on channel reservation scheme for handoff calls. Finite queuing scheme for handoff call is used in first model whereas finite queuing for both handoff as well as new call is considered in the second model. The fuzzy call admission controller is implemented on Mamdani inference scheme taking relative mobility of user and number of reserved channels for handoff calls as input parameters. The output parameter is taken as handoff queue capacity. The fuzzy CAC searches for optimum handoff queue capacity to meet the QoS requirements.

Keywords: CDMA; CAC; queuing; Fuzzy; Mobility; Soft Handoff.

1. Introduction

One of the important features in CDMA cellular network is the use of Soft handoff. Macro diversity is provided in CDMA cellular network by *make-before-break* characteristic of soft handoff. The soft handoff region of the cellular network is a function of two threshold parameters mainly T_ADD and T_DROP [1]. Soft handoff increases system capacity as it reduces interference by transmitting signals at minimum power level required by the BS. Call admission control (CAC) is a technique to limit the number of call connections into the networks. A good CAC scheme must balance the call blocking and call dropping in order to provide the desired QoS (Quality of service) requirements. As dropping of an ongoing call is more annoying to a user as compared to a new call, so handoff priority-based CAC schemes have been widely used [1]. In this paper, a call admission control scheme based on fuzzy logic control scheme is proposed and compared with previously described analytical models [1] [3]. The analytical models developed were based on channel reservation scheme for handoff calls. Finite queuing scheme for handoff call is used in first model whereas finite queuing for both handoff as well as new call is considered in the second model. Finite

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queue model is considered to study the impact of varying the threshold parameters on queue capacity and finally on blocking probabilities. The fuzzy scheme proposed adjusts the handoff queue capacity according to variation in relative mobility and number of guard channels allotted to the handoff calls. The fuzzy logic controller is designed to optimize system resources to keep blocking probabilities at minimum values. The performance measures defined for the analysis are new call blocking probability and handoff request blocking probability.

2. CDMA Soft Handoff

The soft handoff mechanism as described in the CDMA standards is initiated from measurement on forward link channel. The MS (Mobile station) registers the pilot signal strength in term of chip-energy-to-interference ratio (E_C/I_o) of each BS it receives and stores in one of four sets: active, candidate, neighbor and remaining [4]. Pilots are compared with following threshold values and then added or removed from specific set.

A pilot in the neighbor or remaining set is moved to the candidate set, if its E_C/I_o is greater than T_ADD. A pilot in the active or candidate set is moved to the neighbor set, if its E_C/I_o falls below T_DROP for a period of T_TDROP seconds. An MS in Soft handoff region can communicate with two BS (Base station) through two strong pilot signals, respectively. During two way handoff the MS utilizes channel resources from two different BS at same time. This causes an increase in coverage area. During the period the MS is in soft handoff coverage area, it is connected to both the BS [6]. This situation can be realized similar to a call entering in a queue and waiting for a free channel. The capacity of queue for handling handoff calls can be varied by varying the two threshold parameters [5].

3. Queuing Based Call Admission Controller Schemes

3.1. Handoff Queuing based CAC (HQ-CAC)

For the handoff queuing based model it is assumed that C be the limited amount of code channels available in the channel pool. Each channel reserves ‘n’ channels exclusively for handoff calls. For handling the handoff calls queuing scheme is used. A call is forced to terminate when received signal strength from the connected Base Stations falls below the threshold level (T_DROP) prior to the mobile being assigned a channel in the target cell. A finite queue with capacity ‘M’ and FIFO (First in First out) characteristic is assumed at the Base Stations. The System model with priority and finite queue for handoff call is shown in Fig.1 (a).

For the model, it is assumed that new calls generated and handoff calls arriving are Poisson distributed with arrival rates λ_N and λ_H respectively and are uniformly distributes over the area. The duration of a MS in the handoff coverage area depends on parameters like mobile speed, threshold parameters or queue capacity. The channel holding time is also considered to be exponentially distributed with mean rate ‘μ’. The relative mobility ‘a’ is defined as the ratio of rate of handoff call generation to total call generation in the cell [8].
The blocking probability of an originating call (B_N) and blocking probability B_H of a handoff request are given by following expression [2][8][9].

$$B_N = \sum_{i=B}^{C+M} p(i) \text{, where p(i) is the steady state probability} \tag{1}$$

$$B_H = p(C+M) \tag{2}$$

3.2. Complete Queuing based CAC (CQ-CAC)

The second model has some changes as compared to first model. In the second model for handling new and handoff calls, queuing scheme is used. A handoff request is put in the queue Q_H, if BS finds that all channels in target cell are occupied. Queuing scheme is also considered for new originating call. The Queue Q_N, used for new originating call is also dependent on soft handoff threshold and shows a inverse variation with Queue Q_H. As the cell radius is fixed so on increasing the soft handoff area, the capacity of Q_H increases but the capacity of Q_N falls. This leads to increase in blocking of new call. The System model with priority for handoff call and finite queue for new as well as handoff calls is shown in Fig.1(b).

The originating call blocking probability (B_n) and handoff request blocking probability (B_h) are given as:

$$B_n = \sum_{i=B}^{C+N_H} p(i, N_N) \tag{3}$$

$$B_h = \sum_{j=0}^{N_N} p(C + N_H, j) \tag{4}$$

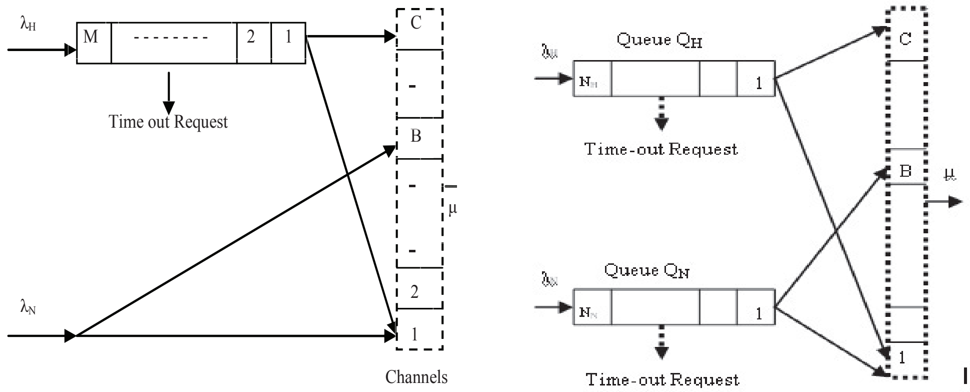

Fig. 1. (a) Model for HQ-CAC Scheme; (b) Model for CQ-CAC Scheme

4. Adaptive Soft handoff based Fuzzy CAC (ASFCAC)

A Fuzzy Logic controller consists of fuzzifier, inference engine, fuzzy rule base and defuzzifier sections. In this paper, a Mamdani based two inputs, one output parameter system is proposed [6] [7]. The input parameters are relative mobility (a) and no. of guard channels (n) and output parameter is handoff queue capacity (M). The structure of proposed FLC is as shown in Fig.2.

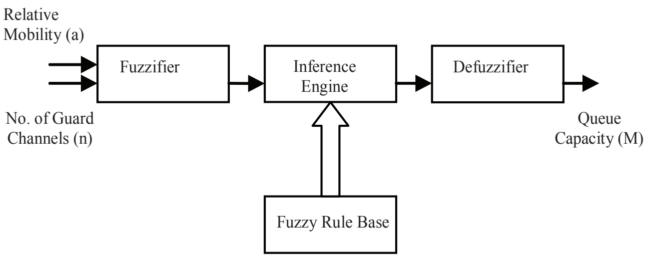

Fig. 2 Fuzzy Logic Controller Structure

The linguistic variable sets for ‘a’, ‘n’ and ‘M’ is defined as follows:
S (a) = {VS, S, M, Sub, F, VF}, range 0 to 1
S (n) = {VL, L, M, H, VH}, range 0 to 8
S (M) = {VL, L, M, Mo, H, VH}, range 0 to 10

The fuzzy rule base is composed of a set of linguistic rule and the expected results. There will be 30(6X5) if-then rules for the proposed two input, one output fuzzy model. The fuzzy control rules are shown in Table.1. shown below.

Table. 1 Fuzzy Control rules for call admission control

Rule No.	**IF** Relative Mobility	**AND** Number of Guard Channels	**THEN** Queue Capacity
1	Very Slow	Very Less	Medium
2	Very Slow	Less	Low
3	Very Slow	Medium	Low
4	Very Slow	High	Very Low
5	Very Slow	Very High	Very Low
6	Slow	Very Less	High
7	Slow	Less	Medium
8	Slow	Medium	Moderate
9	Slow	High	Low
10	Slow	Very High	Low
11	Moderate	Very Less	Very High
12	Moderate	Less	Medium
13	Moderate	Medium	Medium
14	Moderate	High	Low
15	Moderate	Very High	Low
16	Substantial	Very Less	Very High
17	Substantial	Less	High
18	Substantial	Medium	High
19	Substantial	High	Moderate
20	Substantial	Very High	Medium
21	Fast	Very Less	Very High
22	Fast	Less	High
23	Fast	Medium	High
24	Fast	High	Medium
25	Fast	Very High	Medium
26	Very Fast	Very Less	Very High
27	Very Fast	Less	Very High
28	Very Fast	Medium	High
29	Very Fast	High	High
30	Very Fast	Very High	Medium

Aggregated linguistic values are forwarded to defuzzifier section for generating real time crisp outputs. Here, the output generated is the new setting of handoff queue capacity ‘M’ to attain the required QoS parameters.

5. Numerical Results and Discussion

A Comparative analysis of the proposed fuzzy model with HQ-CAC and CQ-CAC is done. For providing the input data to the analytical models, total numbers of channels in the channel pool are fixed at 64. The numbers of reserved channels for handoff call are taken as 10%, 20% and 25% of total channels for different scenarios. The total traffic in the cell is varied form 0 to 80 erlang. The handoff traffic is varied by varying the value of ‘a’, ranging from 0.2 to 0.8. Handoff call queue capacity is fixed at value 6, which depend on the fact that the value of T_DROP can be varied form -15dB to -19dB.

In fuzzy CAC model handoff queue capacity is a dynamic parameter. By taking different datasets of ‘a’ and ‘n’, value of ‘M’ is determined form the fuzzy inference model. These obtained values of ‘M’ are used to determine performance parameters for variation in total traffic.

Fig.3 (a) shows the comparative analysis for new call blocking probability v/s total traffic for the proposed models. The CQ-CAC model offers the least new call blocking probability among the three models. This is due to the fact that new call can be queued for a small duration in this model leading to reduction in new call blocking probability. Fig 3(b) shows variation of handoff call dropping probability w.r.t variation in total load. The results obtained for ASFCAC are better as compared to other two models. As ASFCAC is based on dynamic variation in handoff call queue capacity so it can accommodate more handoff calls by varying T_DROP threshold parameter. This leads to decrement in handoff call dropping probability as compared to the two stochastic models. The variation of forced termination probability of handoff call w.r.t total load is shown in Fig 4(a). As queuing scheme is used for handling both new as well as handoff calls in CQ-CAC scheme. This leads to more waiting or delay for handoff calls in queue to access the channel.. The results obtained for ASFCAC are superior as compared to other two models. The percentage cell utilization among the three CAC schemes is shown in Fig.4 (b). As the proposed algorithm makes dynamical fuzzy decision of the threshold values, it is obvious that the proposed algorithm provides higher cell utilization and lower forced termination probability than others.

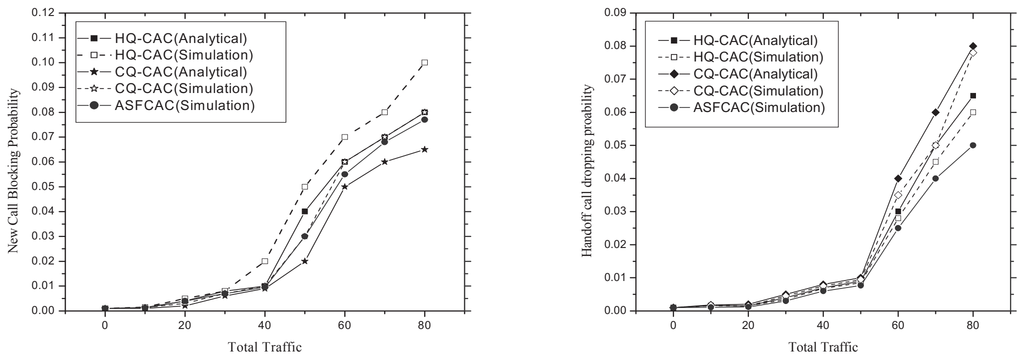

Fig. 3 (a) New call blocking probability v/s Total traffic, (b) Handoff call dropping probability v/s Total traffic

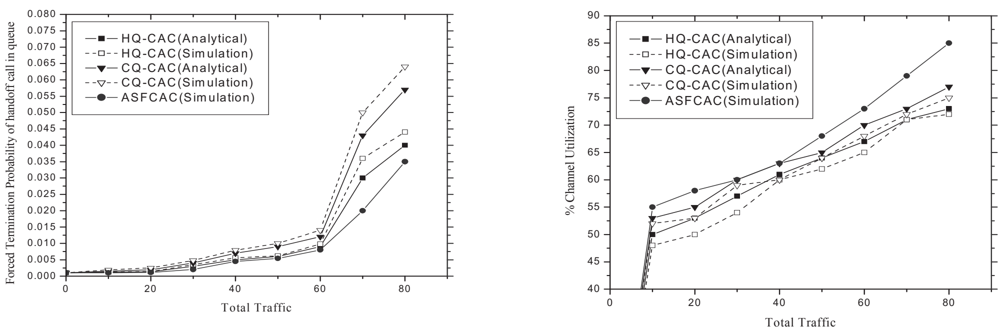

Fig. 4 (a) Forced Termination probability of handoff calls v/s Total traffic, (b) Percent Channel utilization v/s Total traffic

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